

# 52. IWK

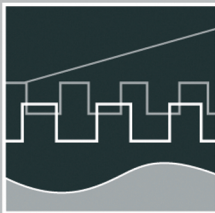
Internationales Wissenschaftliches Kolloquium  
International Scientific Colloquium



**PROCEEDINGS**

| 10 - 13 September 2007

## **FACULTY OF COMPUTER SCIENCE AND AUTOMATION**



## **COMPUTER SCIENCE MEETS AUTOMATION**

### **VOLUME I**

**Session 1 - Systems Engineering and Intelligent Systems**

**Session 2 - Advances in Control Theory and Control Engineering**

**Session 3 - Optimisation and Management of Complex  
Systems and Networked Systems**

**Session 4 - Intelligent Vehicles and Mobile Systems**

**Session 5 - Robotics and Motion Systems**



## **Bibliografische Information der Deutschen Bibliothek**

Die Deutsche Bibliothek verzeichnet diese Publikation in der deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über <http://dnb.ddb.de> abrufbar.

**ISBN 978-3-939473-17-6**

### **Impressum**

- Herausgeber: Der Rektor der Technischen Universität Ilmenau  
Univ.-Prof. Dr. rer. nat. habil. Peter Scharff
- Redaktion: Referat Marketing und Studentische Angelegenheiten  
Kongressorganisation  
Andrea Schneider  
Tel.: +49 3677 69-2520  
Fax: +49 3677 69-1743  
e-mail: [kongressorganisation@tu-ilmenau.de](mailto:kongressorganisation@tu-ilmenau.de)
- Redaktionsschluss: Juli 2007
- Verlag:   
Technische Universität Ilmenau/Universitätsbibliothek  
Universitätsverlag Ilmenau  
Postfach 10 05 65  
98684 Ilmenau  
[www.tu-ilmenau.de/universitaetsverlag](http://www.tu-ilmenau.de/universitaetsverlag)
- Herstellung und Auslieferung: Verlagshaus Monsenstein und Vannerdat OHG  
Am Hawerkamp 31  
48155 Münster  
[www.mv-verlag.de](http://www.mv-verlag.de)
- Layout Cover: [www.cey-x.de](http://www.cey-x.de)
- Bezugsmöglichkeiten: Universitätsbibliothek der TU Ilmenau  
Tel.: +49 3677 69-4615  
Fax: +49 3677 69-4602

**© Technische Universität Ilmenau (Thür.) 2007**

Diese Publikationen und alle in ihr enthaltenen Beiträge und Abbildungen sind urheberrechtlich geschützt. Mit Ausnahme der gesetzlich zugelassenen Fälle ist eine Verwertung ohne Einwilligung der Redaktion strafbar.

## Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52<sup>nd</sup> International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.


All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.

I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.



Professor Peter Scharff  
Rector, TU Ilmenau



Professor Christoph Ament  
Head of Organisation







# CONTENTS

	Page
<b>1 Systems Engineering and Intelligent Systems</b>	
A. Yu. Nedelina, W. Fengler DIPLAN: Distributed Planner for Decision Support Systems	3
O. Sokolov, M. Wagenknecht, U. Gocht Multiagent Intelligent Diagnostics of Arising Faults	9
V. Nissen Management Applications of Fuzzy Control	15
O. G. Rudenko, A. A. Bessonov, P. Otto A Method for Information Coding in CMAC Networks	21
Ye. Bodyanskiy, P. Otto, I. Pliss, N. Teslenko Nonlinear process identification and modeling using general regression neuro-fuzzy network	27
Ye. Bodyanskiy, Ye. Gorshkov, V. Kolodyazhniy, P. Otto Evolving Network Based on Double Neo-Fuzzy Neurons	35
Ch. Wachten, Ch. Ament, C. Müller, H. Reinecke Modeling of a Laser Tracker System with Galvanometer Scanner	41
K. Lüttkopf, M. Abel, B. Eylert Statistics of the truck activity on German Motorways	47
K. Meissner, H. Hensel A 3D process information display to visualize complex process conditions in the process industry	53
F.-F. Steege, C. Martin, H.-M. Groß Recent Advances in the Estimation of Pointing Poses on Monocular Images for Human-Robot Interaction	59
A. González, H. Fernlund, J. Ekblad After Action Review by Comparison – an Approach to Automatically Evaluating Trainee Performance in Training Exercise	65
R. Suzuki, N. Fujiki, Y. Taru, N. Kobayashi, E. P. Hofer Internal Model Control for Assistive Devices in Rehabilitation Technology	71
D. Sommer, M. Golz Feature Reduction for Microsleep Detection	77

F. Müller, A. Wenzel, J. Wernstedt A new strategy for on-line Monitoring and Competence Assignment to Driver and Vehicle	83
V. Borikov Linear Parameter-Oriented Model of Microplasma Process in Electrolyte Solutions	89
A. Avshalumov, G. Filaretov Detection and Analysis of Impulse Point Sequences on Correlated Disturbance Phone	95
H. Salzwedel Complex Systems Design Automation in the Presence of Bounded and Statistical Uncertainties	101
G. J. Nalepa, I. Wojnicki Filling the Semantic Gaps in Systems Engineering	107
R. Knauf Compiling Experience into Knowledge	113
R. Knauf, S. Tsuruta, Y. Sakurai Toward Knowledge Engineering with Didactic Knowledge	119
 <b>2 Advances in Control Theory and Control Engineering</b>	
U. Konigorski, A. López Output Coupling by Dynamic Output Feedback	129
H. Toossian Shandiz, A. Hajipoor Chaos in the Fractional Order Chua System and its Control	135
O. Katernoga, V. Popov, A. Potapovich, G. Davydau Methods for Stability Analysis of Nonlinear Control Systems with Time Delay for Application in Automatic Devices	141
J. Zimmermann, O. Sawodny Modelling and Control of a X-Y-Fine-Positioning Table	145
A. Winkler, J. Suchý Position Based Force Control of an Industrial Manipulator	151
E. Arnold, J. Neupert, O. Sawodny, K. Schneider Trajectory Tracking for Boom Cranes Based on Nonlinear Control and Optimal Trajectory Generation	157



K. Shaposhnikov, V. Astakhov The method of ortogonal projections in problems of the stationary magnetic field computation	165
J. Naumenko The computing of sinusoidal magnetic fields in presence of the surface with bounded conductivity	167
K. Bayramkulov, V. Astakhov The method of the boundary equations in problems of computing static and stationary fields on the topological graph	169
T. Kochubey, V. Astakhov The computation of magnetic field in the presence of ideal conductors using the Integral-differential equation of the first kind	171
M. Schneider, U. Lehmann, J. Krone, P. Langbein, Ch. Ament, P. Otto, U. Stark, J. Schrickel Artificial neural network for product-accompanied analysis and control	173
I. Jawish The Improvement of Traveling Responses of a Subway Train using Fuzzy Logic Techniques	179
Y. Gu, H. Su, J. Chu An Approach for Transforming Nonlinear System Modeled by the Feedforward Neural Networks to Discrete Uncertain Linear System	185
<b>3      Optimisation and Management of Complex Systems and Networked Systems</b>	
R. Franke, J. Doppelhammer Advanced model based control in the Industrial IT System 800xA	193
H. Gerbracht, P. Li, W. Hong An efficient optimization approach to optimal control of large-scale processes	199
T. N. Pham, B. Wutke Modifying the Bellman's dynamic programming to the solution of the discrete multi-criteria optimization problem under fuzziness in long-term planning	205
S. Ritter, P. Bretschneider Optimale Planung und Betriebsführung der Energieversorgung im liberalisierten Energiemarkt	211
P. Bretschneider, D. Westermann Intelligente Energiesysteme: Chancen und Potentiale von IuK-Technologien	217

Z. Lu, Y. Zhong, Yu. Wu, J. Wu WSReMS: A Novel WSDM-based System Resource Management Scheme	223
M. Heit, E. Jennenchen, V. Kruglyak, D. Westermann Simulation des Strommarktes unter Verwendung von Petrinetzen	229
O. Sauer, M. Ebel Engineering of production monitoring & control systems	237
C. Behn, K. Zimmermann Biologically inspired Locomotion Systems and Adaptive Control	245
J. W. Vervoorst, T. Kopfstedt Mission Planning for UAV Swarms	251
M. Kaufmann, G. Bretthauer Development and composition of control logic networks for distributed mechatronic systems in a heterogeneous architecture	257
T. Kopfstedt, J. W. Vervoorst Formation Control for Groups of Mobile Robots Using a Hierarchical Controller Structure	263
M. Abel, Th. Lohfelder Simulation of the Communication Behaviour of the German Toll System	269
P. Hilgers, Ch. Ament Control in Digital Sensor-Actuator-Networks	275
C. Saul, A. Mitschele-Thiel, A. Diab, M. Abd rabou Kalil A Survey of MAC Protocols in Wireless Sensor Networks	281
T. Rossbach, M. Götze, A. Schreiber, M. Eifart, W. Kattaneq Wireless Sensor Networks at their Limits – Design Considerations and Prototype Experiments	287
Y. Zhong, J. Ma Ring Domain-Based Key Management in Wireless Sensor Network	293
V. Nissen Automatic Forecast Model Selection in SAP Business Information Warehouse under Noise Conditions	299
M. Kühn, F. Richter, H. Salzwedel Process simulation for significant efficiency gains in clinical departments – practical example of a cancer clinic	305

D. Westermann, M. Kratz, St. Kümmerling, P. Meyer Architektur eines Simulators für Energie-, Informations- und Kommunikations- technologien	311
P. Moreno, D. Westermann, P. Müller, F. Büchner Einsatzoptimierung von dezentralen netzgekoppelten Stromerzeugungs- anlagen (DEA) in Verteilnetzen durch Erhöhung des Automatisierungsgrades	317
M. Heit, S. Rozhenko, M. Kryvenka, D. Westermann Mathematische Bewertung von Engpass-Situationen in Transportnetzen elektrischer Energie mittels lastflussbasierter Auktion	331
M. Lemmel, M. Schnatmeyer RFID-Technology in Warehouse Logistics	339
V. Krugljak, M. Heit, D. Westermann Approaches for modelling power market: A Comparison.	345
St. Kümmerling, N. Döring, A. Friedemann, M. Kratz, D. Westermann Demand-Side-Management in Privathaushalten – Der eBox-Ansatz	351
<b>4      Intelligent Vehicles and Mobile Systems</b>	
A. P. Aguiar, R. Ghabchelloo, A. Pascoal, C. Silvestre , F. Vanni Coordinated Path following of Multiple Marine Vehicles: Theoretical Issues and Practical Constraints	359
R. Engel, J. Kalwa Robust Relative Positioning of Multiple Underwater Vehicles	365
M. Jacobi, T. Pfützenreuter, T. Glotzbach, M. Schneider A 3D Simulation and Visualisation Environment for Unmanned Vehicles in Underwater Scenarios	371
M. Schneider, M. Eichhorn, T. Glotzbach, P. Otto A High-Level Simulator for heterogeneous marine vehicle teams under real constraints	377
A. Zangrilli, A. Picini Unmanned Marine Vehicles working in cooperation: market trends and technological requirements	383
T. Glotzbach, P. Otto, M. Schneider, M. Marinov A Concept for Team-Orientated Mission Planning and Formal Language Verification for Heterogeneous Unmanned Vehicles	389

M. A. Arredondo, A. Cormack SeeTrack: Situation Awareness Tool for Heterogeneous Vehicles	395
J. C. Ferreira, P. B. Maia, A. Lucia, A. I. Zapaniotis Virtual Prototyping of an Innovative Urban Vehicle	401
A. Wenzel, A. Gehr, T. Glotzbach, F. Müller Superfour-in: An all-terrain wheelchair with monitoring possibilities to enhance the life quality of people with walking disability	407
Th. Krause, P. Protzel Verteiltes, dynamisches Antriebssystem zur Steuerung eines Luftschiffes	413
T. Behrmann, M. Lemmel Vehicle with pure electric hybrid energy storage system	419
Ch. Schröter, M. Höchemer, H.-M. Groß A Particle Filter for the Dynamic Window Approach to Mobile Robot Control	425
M. Schenderlein, K. Debes, A. Koenig, H.-M. Groß Appearance-based Visual Localisation in Outdoor Environments with an Omnidirectional Camera	431
G. Al Zeer, A. Nabout, B. Tibken Hindernisvermeidung für Mobile Roboter mittels Ausweichecken	437
 <b>5      Robotics and Motion Systems</b>	
Ch. Schröter, H.-M. Groß Efficient Gridmaps for SLAM with Rao-Blackwellized Particle Filters	445
St. Müller, A. Scheidig, A. Ober, H.-M. Groß Making Mobile Robots Smarter by Probabilistic User Modeling and Tracking	451
A. Swerdlow, T. Machmer, K. Kroschel, A. Laubenheimer, S. Richter Opto-acoustical Scene Analysis for a Humanoid Robot	457
A. Ahranovich, S. Karpovich, K. Zimmermann Multicoordinate Positioning System Design and Simulation	463
A. Balkovoy, V. Cacenkin, G. Slivinskaia Statical and dynamical accuracy of direct drive servo systems	469
Y. Litvinov, S. Karpovich, A. Ahranovich The 6-DOF Spatial Parallel Mechanism Control System Computer Simulation	477

V. Lysenko, W. Mintchenya, K. Zimmermann 483  
Minimization of the number of actuators in legged robots using  
biological objects

J. Kroneis, T. Gastauer, S. Liu, B. Sauer 489  
Flexible modeling and vibration analysis of a parallel robot with  
numerical and analytical methods for the purpose of active vibration damping

A. Amthor, T. Hausotte, G. Jäger, P. Li 495  
Friction Modeling on Nanometerscale and Experimental Verification

**Paper submitted after copy deadline**

**2 Advances in Control Theory and Control Engineering**

V. Piwek, B. Kuhfuss, S. Allers  
Feed drivers – Synchronized Motion is leading to a process optimization 503



*Horst Salzwedel*

## COMPLEX SYSTEMS DESIGN AUTOMATION IN THE PRESENCE OF BOUNDED AND STATISTICAL UNCERTAINTIES

### Abstract

Complex technical and organizational systems are designed by groups of people departments and/or companies. Because of product uncertainties during development, each of the individual engineers make individual assumptions in their employed design methodologies. Because of the complexity of the system they do not understand the impact of their decisions on the overall systems. Since current design approaches do not consider the impact of this uncertainty on the integrated system, the design specifications are error prone and not validated[1]. The likelihood that a system design does not have critical errors is less than 4%[2].

In this paper design methodologies of individual engineers are modeled and connected by a design process graph to make them executable. Bounded and statistical uncertainties of early design stages are included and bounds on integrated designs based on uncertainties at different design stages are determined using MLDesigner 3.0 [9] Simulation Set capabilities. The new design methodology permits treating uncertainties in early design stages, validate design specifications, and optimize the design flow for different criteria, like quality in design and design cost and verify systems in the presence of this uncertainty.

### Introduction

Complex systems like networked systems in vehicles (aircraft, spacecraft, automobiles, ships, trains, autonomous systems), between vehicles, IT systems, communication or organizational systems can only be developed by groups of people, departments and/or companies. To meet time to market requirements, the system design is partitioned into subsystems and subsystem design is distributed to specialist teams before uncertainties about individual subsystems and interactions between subsystems has been resolved. The individual engineers make assumptions, many based on experience with less complex systems. It is not possible for these engineers to understand the impact of their decisions on these systems. Since

the models passed on for system integration do not include the model uncertainties, the uncertainty of the integrated system is not determined. The integrated system model or design specification is therefore not validated. The likelihood that this design approach will work without critical problems is less than 4% [2]. Very time consuming and expensive integration processes try to resolve conflicts and critical performance issues.

Figure 1 [3] depicts the probability of critical problems as a function of phases of the design process. The probability of critical problems is very high in early design stages and is low in late design stages. These failure rates often result in huge cost overruns for correcting mistakes in complex systems design. Several billion \$/€ projects were terminated due to these failures.

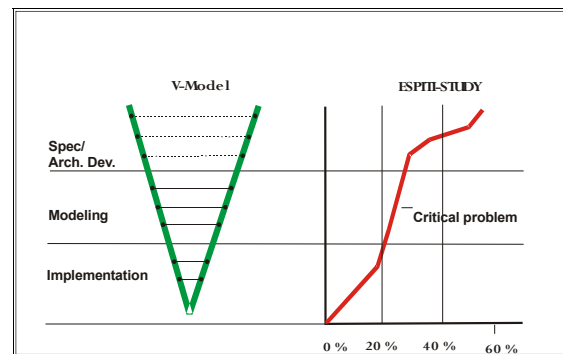


Figure 1: Critical problems in design of complex systems [3]

The analysis of designs shows that most causes for critical design flaws come from poor design specifications. The main reason is that most specifications are on paper only and therefore cannot be validated. The introduction of executable specifications [4] has improved the quality of specifications and significantly reduced the number of design iterations and the cost of design of electronics, software and organizational systems [5]. However, for complex systems, like large IT systems, complex systems design flows and aerospace systems the likelihood that the first design will be right is very low. In addition, in

silicon systems, cost for organizational processes for design and development is increasing exponentially and is already more than 30% for complex chip designs [6].

Development of executable development and organizational process models can catch critical problems in development processes [7] or result in significant improvements and cost savings in organizational processes [8]. However, in most projects these available technologies are not yet employed.

Even so uncertainty plays a major role in early design stages, it is only treated at a subcomponent level and not at the system level. The reason is that as the number of designers/design teams increases, the number of design alternatives increases. For example, 2 different design points of each designer in a 10-person design team, where each team member generates two alternatives, results in  $2^{10}$  different designs. Current manual integration methods cannot cope with this size of design space exploration and verification.

In this paper a system design methodology is developed based on executable design flows. Bounded and statistical uncertainties of early design stages are included and bounds on integrated designs based on uncertainties at different design stages are determined. Examples will demonstrate the new design methodology.

The new design methodology not only permits to treat uncertainties in early design stages, but permit optimizing the design, as well as the design flow for different criteria like quality in design and design cost. Design changes can easily be implemented and design tracking automated.

## Product Uncertainty

Information, knowledge and uncertainty about a product changes significantly during product life time. This knowledge about the product includes knowledge about the product itself, knowledge about the intended use, and knowledge about the environment in which the product is to be used. This uncertainty is bounded and may sometimes be described by bounded parameter sets, bounded statistical distributions, and/or bounded functional behavior described by e.g.  $H^\infty$  norms for continuous systems.

Figure 2 shows a typical behavior of the mean of a product uncertainty. At the start of a development project the product uncertainty,

$U_0$ , is a function on whether the development team has developed similar type of products before. During the development phase the knowledge about the product increases with the learning rate,  $l$ , reducing product uncertainty. This learning curve can be described by an exponential function,

$$U_D(t) = \begin{cases} U_0 e^{-lt} & \forall t < t_D \\ U_0 e^{-lt_D} & \forall t \geq t_D \end{cases},$$

where

$$l = \begin{cases} l_P & \text{for } 0 \leq t < t_P \text{ on paper} \\ l_M & \text{for } t_P \leq t < t_M \text{ model based} \end{cases}$$

for initial slow development on paper and rapid development with executable models, respectively.

At the end of the development phase, the product is delivered to customers, who will find additional insufficiencies that are reported to support and corrected by the development team. The learning effect due to customer testing and support can be described by,

$$L_S(t) = \begin{cases} 0 & \forall t \leq t_D \\ L_{S0}(1 - e^{-l(t-t_D)}) & \forall t > t_D \end{cases}$$

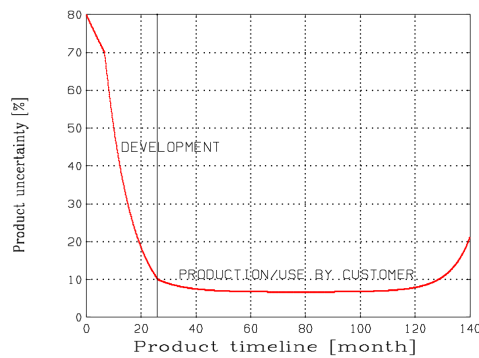


Figure 2: Product uncertainty

However information about a product is also lost during lifetime of a product. The reasons are that people leave development teams, are reassigned, or just not remembering all the decisions which went into the design of a product. Additionally, as time progresses, products are often used for applications that were not considered



during the development phase. These effects impose additional uncertainty on the product, which can be approximated by,

$$U_L = U_{L0} e^{L^2}$$

As development of products with long life times like the Space Shuttle showed, people even have to be called back from retirement in order to overcome this loss of product information.

The uncertainty about a product can then be expressed by,

$$U_P(t) = U_D(t) + U_L(t) - L_S(t)$$

Comparing Figure 1 with Figure 2, we observe that observed occurrence of critical design errors and product uncertainty are highly correlated. We may conclude that critical design errors are primarily due to information uncertainty about a product and design processes that do not consider this uncertainty in the right way and do not validate and verify the system considering this uncertainty.

In the following sections it is shown how uncertainty in use cases, environment and design may be used to determine the system uncertainty. Making the design process itself executable enables its validation, harmonization, and may result in significant savings in development time and risk.

## Complex System Design

Complex systems are always designed and developed by groups of people, departments and/or companies. The system is partitioned into subsystems and subsystems are assigned to different groups. Each group typically has unique knowledge in a particular field and will use their own methodology, models and software for the design of their assigned component. Some will use different software systems.

For design, validation and verification design groups will consider a range of possible parameters and use approximate models for analysis. Different designers/developers will exchange information about their components to other designers according to design or process graphs, Figure 3. The exchanged information typically will not include all assumptions and ranges of uncertainty considered in the design of components. The reason is that some of the uncertainties are very specific to the

field of knowledge used for a component and other designers will not understand this information nor will they be able to properly evaluate potential interactions between components in different subsystems. Other reasons include that the variability of a design may be too large to be considered for manual system integration.

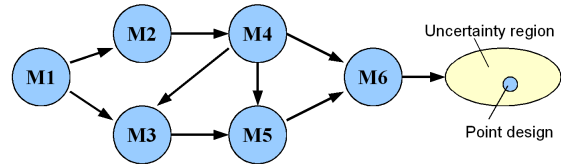


Figure 3: Design process graph

Ten designers doing a conceptual design and each is passing on a minimum and a maximum of one component specific parameter to the integration team, the integration team would require to integrate  $2^{10}$  different system designs for analysis and verification. This would be too time consuming when done manually. It is therefore not done. For system integration, each team will pass on their “best” design to the integration team.

The integrated system is therefore not verified for variability due to uncertainties in subsystems and interactions between components located in different subsystems. As a result, the probability that this coupling is causing critical errors in the design is very high. Testing (expensive and time consuming) should eliminate most critical errors, but customers increasingly find unresolved critical errors after delivery of products. Additionally, different designs based on the same platform design will exhibit very different probability of failures.

## Design Automation

To integrate, validate, and verify different designs (e.g.  $2^{10}$ ), and find the “best” solution between them is an impossible task if done manually. The design must be automated, in order to overcome this problem.  $2^{10}$  iterations of a simulation are not very unusual, dependent on the complexity of the simulation. With distributed simulations and multi core processors even complex simulations can be run for, e.g.,  $\geq 2^{10}$  iterations.

For an automated design, a simulation must be developed that meets the following requirement,

- 1) modules, that are complete independent simulations of design methodologies
- 2) the simulations may be executed by the same or different simulation tools
- 3) a design process graph connects the design methodologies
- 4) Monte Carlo simulation capabilities, in order to be able to analyse sets or ranges of parameters
- 5) simulation model generation, in order to iterate over different architectures
- 6) optimization methodologies that can optimize a design with respect to system level objectives
- 7) distributed simulation to overcome potentially large processing requirements
- 8) the simulation must be connected to a data base, in order to keep track of the large volume of information
- 9) models and data must be stored in a standardized way, in order to ease comparison and analysis

Figure 4 depicts such an automated design process simulation. Each designer has to develop an executable model of her/his design methodology. Process engineers design the process design graph that connect the executable design methodologies.

The simulation generates a set of feasible designs and maps component uncertainties into system uncertainties of coupled designs and can determine which designs meet system requirements for all uncertainties in parameters, architecture, missions/use cases, and environment. If the system performance falls within the permissible performances of the design specifications, the design is verified.

The system uncertainty determined by the range of design variations also depicts the level of uncertainty at a given stage of development. As the different members of the design team get up the learning curve, Figure 2, this uncertainty is going to decrease. Unacceptable levels of system uncertainty can be analyzed, causes determined and eliminated.

The automated design process can be connected to a data base and automatically track design changes and their impact on overall system design criteria, including performance, cost, quality of design.

The design process itself can be modeled and optimized. In [7] the development process for a railway switching system was modeled in MLDesigner and optimized for team selection, team load. Critical components of the development process were identified and eliminated that would have doubled the development time. In [10] the design and development process for automotive electronic control units was optimized using genetic algorithms for finding the optimal combination of design methodologies (team selection), performance (timing, BER, cost and quality. Areas for significant improvements were identified.

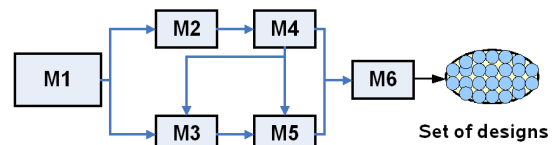


Figure 4: Executable design methodologies, connected by a design process graph

## Implementation of Design Automation

The proposed design automation technology is being implemented and analyzed in the multi domain simulator MLDesigner [9], which already includes multiple execution domains, reducing the need of interfaces to other tools. When necessary, MLDesigner provides hooks that make it easy to interface to tools with similar execution domains. The Monte Carlo simulation capabilities of MLDesigner automatically distribute simulations to other computers that are registered to MLDesigner. MLDesigner 2.7 includes an SQL library for easy data base access.

All MLDesigner models are stored in XML, supporting mapping though XSLT scripts. Baumann [11] is developing network building blocks and XSLT based mapping functions to automatically map functional level models into architecture and combined architectural and functional models into implementations. Fischer

[12] is developing system level architecture optimization technology which generates the information about the optimal architecture, that can then be read by the mapping functions of Baumann. Riehmer [13] is developing a standardized XML based data format for MLDesigner and Octave that is compatible with the Open Office Document Standard and can be read and generated by spreadsheets from Open Office and Microsoft Office. Genetic algorithm optimization methods have been developed to optimize MLDesigner models of design processes for performance and quality. These algorithms will be extended for optimization in automated design processes.

The next version of MLDesigner (3.0) will provide new simulation set capabilities which have been developed to make it possible to connect independent simulations, using UML activity diagram syntax that describes control flow, design flow, work flow and/or analysis flow connecting the elements of the simulation set. Parallel and sequential execution will support automated distributed simulation of independent simulations. The design process graph can be defined by the standard graphical model editor of MLDesigner, Figure 5.

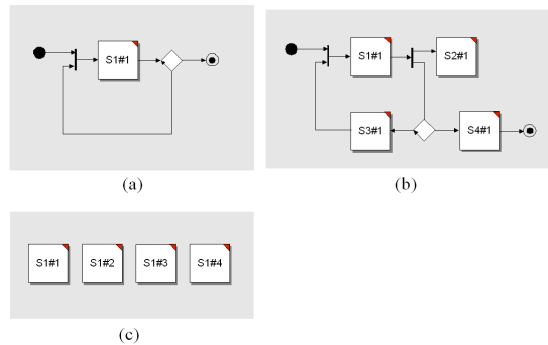


Figure 5: Sequential executions with termination conditions (a,b) and parallel executions (c) of MLDesigner simulation sets

## Examples

This sections show two very simple examples using the simulation set capabilities of MLDesigner 3.0 and using two external tools --- SatLab and Octave --- for analysis. These low complexity examples can be verified directly in MLDesigner or by SatLab and Octave.

Example 1: The accuracy of a least squares signal processing algorithm is analyzed for the example of fitting a fourth order polynomial

$$y_i = p_1 + p_2 x_i + p_3 x_i^2 + p_4 x_i^3 + v_i, \quad v = N(0, R_v)$$

through a data set with normally distributed measurement errors. 30 different data sets are generated by MLDesigner and 30 to 1400 measurements are taken of these data for parameter estimation. The parameter estimation is performed by SatLab. Figure 6 shows how the parameter estimation error change as a function of number of measurements taken.

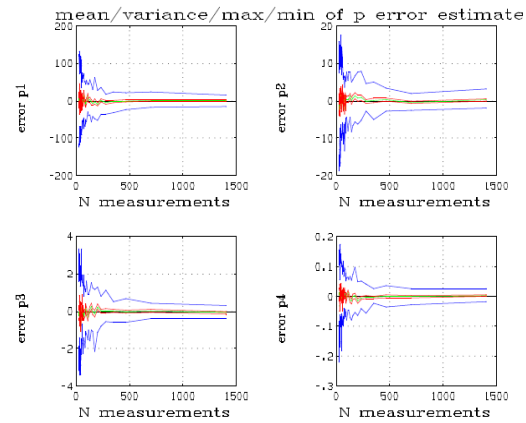


Figure 6: Analysis results for accuracy of least squares parameter estimation algorithms

Example 2: Chapter 10.3 of Reference 14 shows a design methodology for a design specification of a longitudinal controller for an aircraft (Boeing 747). Variations in loading and fuel consumption will affect aircraft dynamics parameters and flight behavior. These parameters changes are bounded by minimum and maximum weight and the permissible minimum and maximum center of mass location for the aircraft. Using maximum and minimum values instead of nominal values for seven longitudinal aircraft dynamics parameters, results in  $2^7=128$  different dynamic models of the aircraft pitch behavior. Figure 7 shows minimum, mean and maximum behavior of an altitude change of the aircraft are affected by 40% changes in pitch parameters

$X_u, X_w, Z_u, Z_w, M_u, M_w$ , and  $M_q$ . The results show that the chosen closed loop eigenvalues for the autopilot design is very robust

against parameter changes and passengers will hardly notice the changes in behavior.

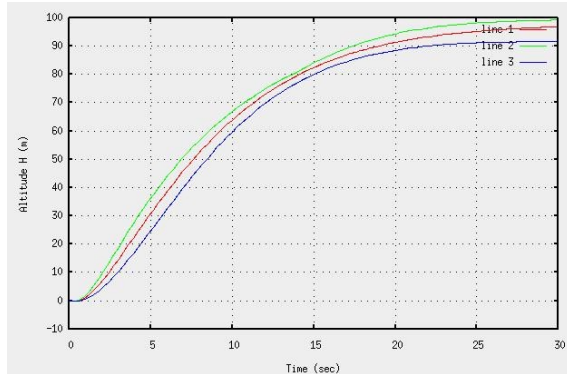


Figure 7: Aircraft altitude hold autopilot response verification for bounded aircraft parameter changes of  $\pm 40\%$

## Conclusions

Uncertainty of information in design of complex systems is the primary reason for critical problems and expensive corrective actions. A design automation methodology based on coupled models of design methodologies of participating design groups and developers is proposed that overcomes this critical design problem and enables large design space exploration and verification of uncertain systems. The developed methodology permits verification of system level functional and performance behavior in the presence of system uncertainty. Digital as well as analog systems may be verified by this methodology. A methodology for implementing this methodology by the simulation set capabilities of the development tool MLDesigner is shown. Two simple examples show how statistical and bounded system uncertainties may be mapped into bounded system behavior by automating design and analysis using an executable design flow.

## REFERENCES

- [1] John Hines, We Don't Do Design Correctly!, Keynote speech at IEEE 9<sup>th</sup> International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems, MASCOOTS 2001, Cincinnati, Ohio, Aug. 15-18, 2001.
- [2] Bruno Schienmann, *Kontinuierliches Anforderungsmanagement*, Addison-Wesley, 2002. – ISBN 3-8273-17-87-8

[3] Horst Salzwedel, Mission Level Design of Avionics, *AIAA-IEEE DASC 04 - The 23rd Digital Avionics Systems Conference 2004*, Salt Lake City, Utah, USA, October 24-28, 2004.

[4] Holger Rath, Gunar Schorch, Horst Salzwedel, Simulationsumgebung für Bordnetze - Bordnetz-Spezifikationen modellieren und validieren, *Hanser automotive*, 5-6.2006, S. 34-38, Carl Hanser Verlag München, ISSN 1860-5699.

[5] Horst Salzwedel, Frank Richter, Matthias Kühn. Standardized Modeling and Simulation of Hospital Processes - Optimization of Cancer Treatment Center, *International Conference on Health Sciences Simulation, HSS '07*, San Diego, California, January 14-18, 2007.

[6] Ralf Pferdmeiges, Presentation on current challenges in chip design, *EDACentrum Workshop: System Planning*, Hannover, Germany, November 30, 2006.

[7] Manuela Tröbs, *Analyse, Optimierung und Simulation des Simis IS Entwicklungsprozesses*, Thesis, Siemens/Technical University Ilmenau, June 2006.

[8] Matthias Kühn, Frank Richter, Horst Salzwedel, Process simulation for significant efficiency gains in clinical departments – a practical example of a cancer clinic, to be presented at 52<sup>th</sup> International Scientific Colloquium, Ilmenau, September 10-12, 2007.

[9] MLDesigner® Manual v3.0,  
<http://www.mldesigner.com>

[10] Tom Dengler, Horst Salzwedel, Optimierung von komplexen Entwicklungsprozessen mittels simulationsgestützter Prozessanalyse, to be presented at 52<sup>th</sup> International Scientific Colloquium, Ilmenau, September 10-12, 2007.

[11] Tommy Baumann, Horst Salzwedel, Mapping of Electronic System Level (ESL) Models Into Implementation, *DATE'07*, Acropolis, Nice, France, April 16-20, 2007.

[12] Nils Fischer, *Design of a Plug-and-Play Development Environment for Optimizing Avionics Systems Architectures*, Thesis, Airbus/Technical University Ilmenau, July 2007.

[13] Stefan Riehmer, *Standardizing Data Storage for MLDesigner and Octave using the Open Office Document Standard*, Thesis, Technical University Ilmenau, August 2007.

[14] Gene Franklin, David Powell, Abbas Emami-Naeini, *Feedback Control of Dynamic Systems*, Pearson Prentice Hall, New Jersey 2006.

## AUTHOR:

Horst Salzwedel, MLDesign Technologies, Inc.,  
horst@mldesigner.com